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## Range extension of the Atlantic herring *Clupea harengus* (Clupeiformes: Clupeidae) southern part of the Northeast Atlantic Ocean

by

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**Résumé.** – Extension de l’aire de répartition du hareng de l’Atlantique *Clupea harengus* (Clupeiformes: Clupeidae) dans le sud de l’Atlantique Nord-Est.

Cinq spécimens de hareng de l’Atlantique, *Clupea harengus*, ont été capturés dans les eaux du nord de l’Espagne (Galice et Asturies) au cours des dernières années. L’identification de deux spécimens conservés a été confirmée par des paramètres morphométriques et méristiques ainsi que par barcoding moléculaire. Ces captures représentent les premiers signalements pour les eaux de Galice et des Asturies et les signalements les plus méridionaux pour l’océan Atlantique Nord-Est. La présence de cette espèce dans la partie sud du golfe de Gascogne pourrait être liée à des événements climatiques.

**Key words.** – Atlantic herring – First record – Cold-water fishes – DNA barcoding – Distribution.

The Atlantic herring *Clupea harengus* Linnaeus, 1758 is a pelagic clupeid, schooling, plankton-feeding species that inhabits the coastal areas from inshore to well offshore waters, at depths to 200 m (Whitehead, 1986). This target species has been crucial for food security and economic development in northern Europe (Martinez-Barrio *et al.*, 2016). Its fishery currently ranks among the five largest fisheries in the world, with nearly 2 million tons of fish landed annually in the last years (FAO, 2010-2019).

This species is distributed on both sides of the North Atlantic Ocean. In the western Atlantic, it ranges from Labrador to Cape Hatteras; in the eastern Atlantic, from the northern part of the Bay of Biscay to Greenland, and to the East into the Barents Sea (Whitehead, 1985, 1986). In the northeastern Atlantic, a large number of intraspecific groups (races, stocks, and populations) are distinguished by their spawning grounds and seasons, otolith morphology and meristic characters (Berg *et al.*, 2017).

### MATERIAL AND METHODS

Five specimens of *Clupea harengus*, ranging from 28 cm and 30 cm in total length, were recorded in the waters of northern Spain from 2009 to 2018, at depths between 34 and 114 m (Tab. I). The first specimen was caught in 2009 by an artisanal fishing vessel using gill nets. The others were caught during the annual bottom-trawl surveys for the assessment of demersal and benthic stocks (“Demersales” surveys), which are carried out every autumn on soft bottoms along the continental shelves of Galicia and the Cantabrian Sea by the Instituto Español de Oceanografía. Two specimens caught in 2009 and 2014 were examined. The morphometric and meristic characters were recorded in fresh following Whitehead (1985, 1986), and then the specimens were preserved in 70% ethanol and deposited in the fish collection of the Museo Luis Iglesias de Ciencias Naturais in Santiago de Compostela, with the reference numbers MHNUSC25163-1 and MHNUSC25163-2 (Fig. 1).

A muscle tissue sample from both specimens was submitted to DNA purification and sequencing of the standard 5’ barcoding region of the mitochondrial gene cytochrome c oxidase subunit I (*COI*), following procedures previously described (Barros-García *et al.*, 2016). PCR amplification was carried out with Thermo Scientific Phire Green Hot Start II PCR Master Mix and primers FF2d (5’-TTCTCCACCAACCACAARGAYATYGG-3’) and FR1d (5’-ACCTCAGGGTGTCCGAARAAYCARAA-3’), obtaining 652 nucleotides-long DNA barcodes. Specimen and collection data, sequences, and trace files are available on the Barcode of Life database (BOLD; <http://www.boldsystems.org>) in the project

Table I. – Location of records and data for specimens of *Clupea harengus* caught in northern waters of Spain.

Date	Latitude	Longitude	Depth (m)	TL (cm)	Weight (g)	Gear
19/05/2009	42.4397	-8.9214	35	28	–	Gillnet
25/09/2014	43.2477	-9.1234	95	30	190	Trawl
05/10/2014	43.6897	-6.2747	135	28	155	Trawl
21/09/2018	42.6125	-9.2187	101	29	197	Trawl
07/10/2018	43.6867	-6.0793	114	28	164	Trawl

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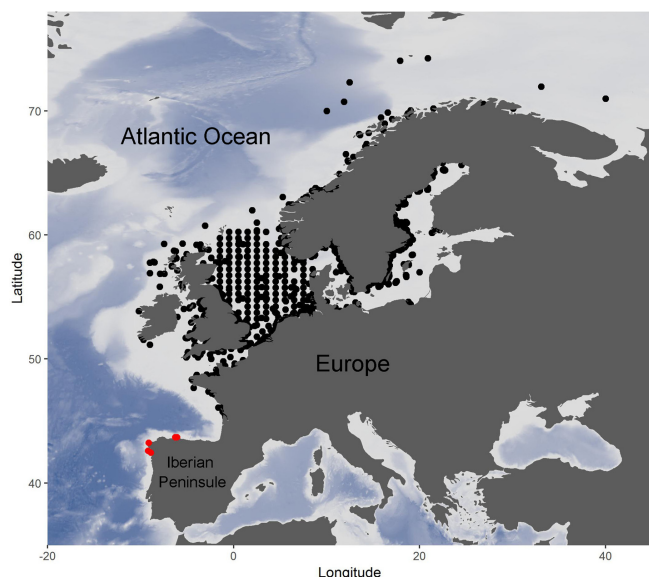


Figure 1. – Map showing the location of records of *Clupea harengus* in the European Atlantic waters. The black dots constitute the historical captures reported in GBIF and the red dots represent the present records in the North of Spain between 2009 and 2018.



Figure 2. – *Clupea harengus*. A: MHNUSC25163-1, 285 mm TL; B: MHNUSC25163-2, 300 mm TL.

file “Marine fishes from Galicia” with Process IDs FIGAL010-19 and FIGAL011-19 and in the GenBank database under accession numbers MK504635 and MK504636. These sequences were aligned with others from *C. harengus*, Pacific herring *Clupea pallasii* Valenciennes, 1847 and European pilchard *Sardina pilchardus* (Walbaum, 1792), obtained from BOLD. The taxonomic identity of the samples was explored by means of a Neighbor-Joining analysis (Saitou and Nei, 1987). The divergence among sequences was calculated as the number of base differences per site (*p*-distances).

### RESULTS

A dot distribution map was created based on georeferenced data reported in online marine biogeographic databases (GBIF, 2019) showing the records in the north of Spain (Fig. 2).

The body is elongated and highly depressed, its height 4.6 times in the standard length; mouth large, reaching posteriorly to the midline level of the eye; lower jaw projecting; snout greater than eye diameter, 0.7 times in eye; eye large, 4.4 and 4.7 times in head; no median notch on the upper jaw; operculum smooth, without radiating bony striae; pelvic fins inserted posterior to the dorsal fin origin; scales large and cycloid; colour bright silver, darker on the back with no distinctive dark spots on the body or fins. The main morphometric and meristic characters are showed in table II.

Molecular analysis identifies the two specimens tested as belonging to the species *Clupea harengus*, as they unambiguously group with other sequences of the same species, the mean distance between all of them being 0.3%. The average distance separating this cluster from that formed by sequences of its sister species *C. pallasii* is 1.5% and the distance from the group formed by barcodes of *S. pilchardus* is greater than 17%. The two sequences of *C. harengus* under analysis differ only in two nucleotide positions.

### DISCUSSION

Meristic and biometric measures are in agreement with previous diagnoses and descriptions of *Clupea harengus*. So far, this species was not reported south of the estuary of the River Garonne (France) (GBIF, 2019). Therefore, the present records confirm its presence on the northern coasts of Spain, establishing the southernmost record in the eastern Atlantic Ocean at 42.4397°N-8.9214°W, in Galician waters.

Table II. – Measurements in mm, body proportions in percentage of Standard length (%SL) and counts carried out on the two specimens of *Clupea harengus*.

	MHNUSC25163-1	% SL	MHNUSC25163-2	% SL
Total length	285		300	
Fork length	253		270	
Standard length	240		255	
Head length	56	23.3	57	22.4
Preorbital length	18	7.5	18	7.1
Eye diameter	12	5.0	13	5.1
Postorbital length	26	10.8	26	10.2
Interorbital distance	11	4.6	11	4.3
Mouth length	27	11.3	25	9.8
Maxilla width				
Predorsal length	120	50.0	130	51.0
Dorsal fin base length	30	12.5	32	12.5
Preanal length	189	78.8	197	77.3
Anal fin base length	25	10.4	27	10.6
Prepectoral length	52	21.7	50	19.6
Pectoral length	37	15.4	36	14.1
Prepelvic length	132	55.0	141	55.3
Pelvic length	23	9.6	24	9.4
Caudal peduncle depth	18	7.5	18	7.1
Body depth	52	21.7	56	22.0
Body width	28	11.7	28	11.0
No. of dorsal fin rays	18		19	
No. of anal fin rays	17		18	
No. of pectoral fin rays	18		17	
No. of pelvic fin rays	9		9	
Branchiostegal rays	8		8	
Gill rakers	21+42		26+45	

The fish species composition in the North of Spain includes groups of boreal and subtropical origin. Although Lusitanian species represents the majority of the fish fauna in the region, there is also a minor group of warm- and cold-water adapted species inhabiting these waters (Bañón *et al.*, 2010). Although the occurrence of new warm-water fishes related to global warming is the most common phenomenon in this area (Bañón *et al.*, 2017), the presence of new cold-water fishes also occurs, but less frequently. *Clupea harengus* is the last cold-water adapted species added to the list of Spanish distributed fishes. Other species such as the beaked redfish *Sebastes mentella* Travin, 1951 (Fernández-Zapico *et al.*, 2012) and the northern wolffish *Anarhichas denticulatus* Krøyer, 1845 (Rodríguez-Cabello *et al.*, 2015) have also been recently reported in the north of Spain for the first time, both establishing new southern limits of distribution.

The causes of the current presence of *C. harengus* could be related to climate variations. Indeed, the distribution of some pelagic fishes, such as *S. pilchardus* and *C. harengus*, have shown pronounced latitudinal distributional responses to seasonal change of sea temperatures in the historical records from the northeast Atlantic Ocean, in relation with alternations of cycles of warm and cold periods (Heath *et al.*, 2012). Dynamics of abundance and migrations of populations of *C. harengus* in the eastern North Atlantic vary in synchrony with the warm (positive) and cool (negative) phases of the Atlantic Multidecadal Oscillation (AMO). It is during negative AMO phases when good recruitment and large incoming year classes occur, that will form the basis of the herring fishery in the following years (Alheit *et al.*, 2014). There are hints of a transition to a relatively cold period at this moment in the North Atlantic (McCarthy *et al.*, 2015). The AMO index has been decreasing in the last years and, during the 2014-2016 period, it has become marginally negative, with an average sea surface temperature anomaly of about  $-0.1^{\circ}\text{C}$  (Frajka-Williams *et al.*, 2017). Therefore, a colder period seems to favour the abundance and the migration of *C. harengus* in the eastern North Atlantic, and could be the cause of this apparent expansion to the south. If this hypothesis is true, and a progressive cooling occurs in the next years in the North Atlantic Ocean, a greater presence of *C. harengus* in the northern waters of Spain should be expected.

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